METHODS AND RESULTS OF DEFINITE RAIN MEASUREMENTS

III. DANZIG REPORT (1)

By Prof. Dr. H. KOSCHMIEDER

[Danzig, Germany]

As is well known, Jevons showed in 1861 that the rain gage produces a disturbance of the air currents, and thereby a disturbance in the distribution of precipitation of such a kind that a part of the rain is carried past the gage, and that the amount of variation from the true rainfall increases with increasing wind velocity. The disturbance which is caused by the instrument itself we shall call the "instrument disturbance" or the "Jevons effect." To correct this, many devices have been invented, of which the best known are the Nipher "funnel shield" and the Wild "fence." As a criterion for the usefulness of such a shelter arrangement the rain gage which under the same conditions gave the greatest quantity, and that quantity, were considered the most accurate. However, Bastamoff and Witkiewitsch (2) showed in 1926 that the amount of rain is not a useful criterion since under certain conditions the influence of the shelter can even give too great amounts of rain, that is, larger amounts than a part of the earth's surface sufficiently removed from all disturbances would receive.

Without knowledge of this important Russian investigation I undertook to construct (3) a rain gage which through its aerodynamic form "a priori" proves that the air movement in its surroundings remains definite, that is, that the air movement parallel to the earth's surface is not noticeably disturbed by the rain gage.

The sunken rain gage (4).—The task was solved in a simple way by sinking the whole rain gage in the ground in such a manner that the receiving surface is level with the earth. This arrangement offers three advantages.

1. The influence of the form of the rain gage on the air currents disappears completely.

2. The influence of the necessary catchment surface on the air currents in its vicinity is reduced to a minimum through the fact that this surface lies in the layer of least air movement.

3. The influence of the turbulent vertical movements is likewise reduced to a minimum, since these disappear at the earth's surface. Therefore, there is no longer any reason evident that a disturbance of the air currents and a disturbance of the distribution of precipitation should appear with the sunken gage.

On the other hand, the sinking of the catchment area in the earth's surface brings in itself the danger that the drops falling on the ground near the gage will splash and in part fall into the sunken rain gage in the form of spray, and thus falsely indicate too great an amount of rain.

This is the only fundamental objection which can be raised against the sunken rain gage. However, methods can be mentioned which eliminate the spray, and it can be proven whether these methods suffice. After adopting the principle of the sunken rain gage the chief task of the investigation was to test the question of spray. In that the method in itself is capable of proof my investigations go beyond the former ones.

The proof whether the shelter is sufficient against spray or not now follows in a very simple way, through comparing two similar rain gages whose shelter arrangements have different sizes.

If the shelter arrangement is insufficient, then the rain gage provided with the smaller shelter must, as a result of the spray, give a greater rainfall than the one with the larger shelter arrangement. If, on the other hand, the measured amount of rain in the case of both gages is equal, the shelter is sufficient.

The screen in my experiments consisted either of a circular brush whose bristles are turned up and which hold the incident rain drops, the *brush rain gage* (5) or a honeycomb shaped, iron grate 5 centimeters thick made of thin sheet iron with 4 by 4 cm openings which permit the rain drops to fall through, but which act on horizontal air currents almost like a continuous surface, *the honeycomb rain gage* (6).

The structure of the brush rain-gage is shown in figure 1. Figure 2 shows it on the peak of the Schneekoppe, and, rising beside it an unsheltered Hellmann-Fuess gage for comparative measurements. The grate of the honeycomb rain gage is shown in figure 3. It is sunk in the same way as the brush of figure 1. Different sizes of each kind of sunken rain gage were compared two at a time. In order, however, to determine the quantity of the Jevon's effect and to compare the different types of
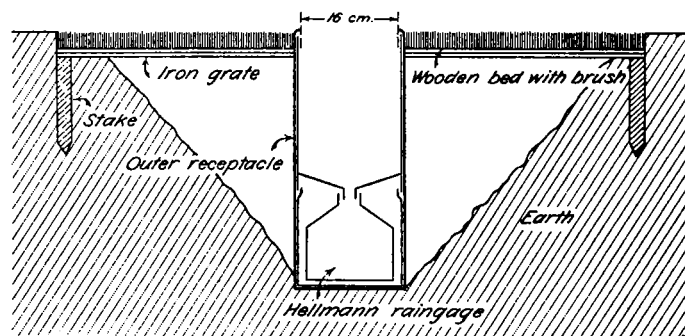

FIGURE 1.—The structure of the sunken rain gage.

rain gage with respect to the uncertainty of single measurements, two normal, unprotected, Hellmann-Fuess rain gages as well as the observatory gage were used. The following are abbreviations for the gages:

Bg = Big brush rain gage, brush diameter 150 cm
Bk = Small brush rain gage, brush diameter 100 cm
Wg = Big honeycomb rain gage, comb diameter 150 cm
Wk = Small honeycomb rain gage, comb diameter 100 cm
} sunken.

I and II = Hellmann-Fuess rain gage, catchment area 110 cm high.
$St.$ = Station rain gage, 150 cm high {with Wild "fence" 130 cm
R = Registering rain gage, 150 cm high { high.

Each of the rain gages consisted of three parts, and each had a catchment area of 200 square centimeters except that *St.* had one of 500 square centimeters. The rain gages were tested on the Scheneekoppe in the Riesengebirge. The Scheneekoppe was chosen because at that place there frequently occur heavy rains, often accompanied by high wind velocities. The rain gages stood on the northwest side of the peak and with SE.–WSW. winds lay in the wind shadow of the mountain, or in an extremely turbulent wind movement. A fairly orderly air current over the field of the rain gages is present only with WNW.–N. winds. Therefore only these wind directions are to be used for the determination of the Jevons effect.

II. *The Spray Water.*—The proof that no spray falls into the sunken rain gage is equality of the amounts of

rain which are measured by the upright and the sunken gages so soon as calm or light winds prevail, and the Jevons effect is not noticeable. This condition is completely fulfilled by the brush rain gages, since the 16 cases of rain with low wind velocities give:

$$Bg = 141.1, \quad I = 138.8, \quad St. = 142.0 \text{ mm}$$

The differences are entirely unimportant, also Bk agrees well with Bg. The years 1931–32, in which Bk lay beside Bg, gave $Bg = 39.6$, and $Bk = 38.7$. Also the excessive rains gave agreement in amount so long as the Jevons effect was not operative. If we take in addition those cases in which the rain gage field lay to the leeward of the mountain, the five excessive rains of the years 1928–32 gave $Bg = 166.8$, $I = 167.7$, $St. = 163.4$ mm.

So soon as the Jevons effect makes its appearance there comes the necessary and sufficient condition for the defective measurement due to spray, in that Bk gives no larger rainfall than Bg. In the years 1931–32 the rain gages placed near one another gave the following amounts of rain.

Wind (7)	Bg	Bk	I	II
	mm	mm	mm	mm
C., 0–3 m/s	39.6	38.7	39.5	38.2
S.–SW., 3–13 m/s	82.0	85.3	90.2	88.1
S.–SW.≧14 m/s	114.5	118.6	121.9	101.1
WNW.–N, 3–13 m/s	88.0	87.3	67.8	69.2(8)
WNW.–N.≧14 m/s	233.2	238.4	112.6	125.1(9)
Sum	557.3	568.3	432.0	421.7

With S.–SW. winds the rain gage area lies in the wind shadow. The first three lines give approximately the same rain amounts for the tall unprotected gages I and II as for Bg and Bk. With WNW.–N. winds the Jevons effect appears and the unprotected rain gages show marked amount of error as compared with the sunken ones. On this point, more details later. We are now comparing Bg and Bk. The table shows that they practically agree. The excess of Bk over Bg amounts to less than 2 percent of the amount measured by Bg. The difference is entirely insignificant.

Downpours of rain provide a further check: If spray water were present then in downpours the ratio of Bg to I must have been greater than in moderate rains. This does not hold true, as is shown by a thoroughgoing investigation of eight downpours with a total fall of 337 mm. Consequently, the large brush represents a complete protection against spray; therefore the brush rain gage can be considered as a normal rain gage.

The honeycomb rain gages in 1931–32 gave smaller values than the brush rain gages. From this it may be thought that the honeycomb gage presents a better protection against spray than the brushes. There is something wrong, for in the first place it has just been proven that the brush represents a complete protection, and in the second place the small honeycomb rain gage gives a smaller quantity of rain than the larger one, namely, $Wk = 518.2$ as compared with $Wg = 531.8$, while Wk must have been greater than Wg if spray were present. To what these disagreements are related must still be made clear. Until then, the experiments with the honeycomb gage cannot be regarded as closed. However, the disagreements are small, especially in the cases in which a wind influence appears. In the above-named wind groups the percentage deviation with respect to Bg amounted to:

	C.	SW. 1	SW. 2	NW. 1	NW. 2	Average
	Percent	Percent	Percent	Percent	Percent	Percent
Wg	−8.6	−3.9	−4.5	+2.3	−6.8	−4.6
Wk	−15.9	−16.2	−11.5	+3.2	−3.9	−7.0
I	−0.3	+10.0	+6.5	−23.0	−51.7	−22.5
II	−3.5	+7.4	−11.7	−21.4	−46.4	−24.4

Thus with northwest winds the deviations of the comb gages with respect to Bg amount to only one tenth of the deviation of the upright rain gage. Moreover, its sign changes, while the sign of the variations of the upright gage remains the same.

I believe that in other lands—for example, on the flat islands of the North Sea—a still better agreement would result between the comb and brush rain gages than on the Schneekoppe, where the air movement is somewhat regular only in the case of northwest winds.

Such a result would be very desirable, since the honeycomb rain gage shows important technical advantages when compared with the brush rain gage. If it is zinc-coated, it is sufficiently independent of the influence of moisture; it is not clogged by transported sand which readily falls through the openings, and it can be walked on without being damaged.

III. The uncertainty of the single measurements could be determined during the series of experiments, since there were available two patterns of each rain gage. A reasonable measure for the average uncertainty of a single measurement of each of the rain-gage types would be given by the expression $\triangle B = \dfrac{1}{n}\Sigma \left| Bg_i - \dfrac{Bg_i + Bk_i}{2} \right|$,

$\triangle W = \dfrac{1}{n}\Sigma \left| Wg_i - \dfrac{Wg_i + Wk_i}{2} \right|$, $\triangle H = \dfrac{1}{n}\Sigma \left| I_i - \dfrac{I_i + II_i}{2} \right|$, where n is the number of the occasionally available pairs of values, and $i = 1 \dots n$ is the index with respect to which the summation is taken. It becomes:

	$\triangle B$	$\triangle W$	$\triangle H$	($\triangle St.$)	
NW. 1	±3.5	±3.5	±5.8%	(±5.6%)	St. compared with $\dfrac{Bg+Bk}{2}$
NW. 11	±6.5	±5.7	±15.2%	(±11.8%)	

Thus the uncertainty of a single measurement with the sunken rain gage amounts to only one half to one third of the uncertainty with the upright gage.

IV. *The instrumental disturbance of the normal unprotected rain gage.*—Since, as has been shown, the sunken brush rain gage can be considered as a normal rain gage, the Jevons effect of the normal upright rain gage can be established quantitatively with it, as a function of the wind velocity. And indeed there is interest in the dependence of the Jevons effect on that velocity of the wind which prevails at the height of the catchment surface of the upright gage; that is, at 110 cm above the ground. Therefore, in 1931–32 the wind velocities at this height above the rain measuring field were observed and for the preceding years they were reduced to this height by the aid of comparative measurements on the tower. (For full details, reference may be made to the original communication.) Here it may merely be mentioned that the wind velocity at the height of 110 cm was two thirds to one half that which was measured on the tower of the observatory, 17.2 m above the ground.

FIGURE 2.—The sunken brush rain gage on the Schneekoppe. (Behind it a normal upright Hellmann-Fuess rain gage.)
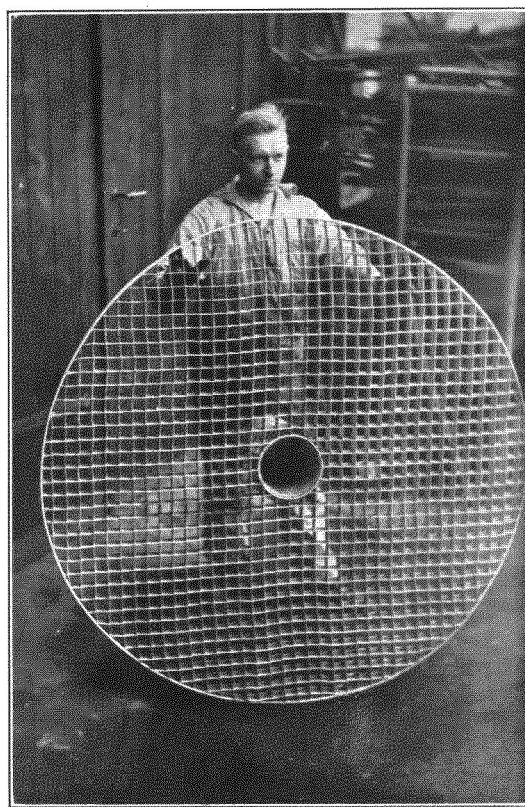

FIGURE 3.—The comb grate of the honeycomb rain gage. In the middle, the outer vessel, in which the usual 3-piece Hellmann-Fuess gage is placed.

The mean deficits were calculated for the different intervals of wind velocity whose main values are evident from figure 4. These are marked in figure 4 by circles. It is seen that up to the velocity of 12 m.p.s. the scatter from the smoothed curve is small, therefore up to this value the curve can be considered accurate. It gives the following smoothed deficits, D, for the upright normal gage and the following reduction factors, f, relative to the wind velocities, v, prevailing at the height of 110 cm:

$v=0$	2	4	6	8	10	12	(14)	16 m/s
$D=0$	4	10	19	29	40	51	(62)	(71) %
$f=1$	1.04	1.11	1.23	1.41	1.67	2.0	(2.6)	(3.4)

At about 9 m.p.s. the results of the upright gage are to be multiplied by 1.5 in order to obtain the true amount of rain; at about 12 m.p.s. by 2, at about 15 m.p.s. by 3.

These figures hold for ordinary rains. In very fine mists, whose intensity does not exceed 0.2 mm per hour, the upright gages give a greater rainfall than the sunken ones, a result, perhaps, of the mechanical depositing of drops. An upright brush rain gage, which was not mentioned above, also gave an excess of rainfall. With it the excess of rainfall relative to $(Bg+Bk)/2$ was 12 percent under NW. 1, and even 44 percent under NW. 2. This shows that even a horizontal surface, or a surface parallel to the ground like the elevated brush, presents an obstacle to the wind, since the wind is never directed horizontally but continually oscillates about the horizontal because of turbulence.

For this reason the sinking of the rain gage in the surface of the ground appears to be the sole possibility of preventing every noticeable effect of the rain gage on the air movement and the distribution of precipitation and of measuring the rain without error. However, the practical importance of the sunken rain gages is decreased in that they are useless for the measurement of snow (and perhaps hail). Nevertheless, it would be unfair to require of *one* instrument the solution of different problems; one must be fairly well satisfied if one question is correctly solved. To me there appeared an unconditioned necessity of producing proof of this, since the similar propositions of Stevenson and Buchan have remained unfruitful because they lack reference to definite proof.—*Translated by R. J. Martin.*

LITERATURE CITED

(1) II. Report Mo. Wea. Review 58, 1930, p. 439, Measurements of visibility at Danzig.
   I. Report Mo. Wea. Review 56, 1928, p. 305, Methods and results of definitive air pressure measurements.
(2) Bastamoff et Witkiewitsch, Les spectres aerodynamiques des pluviometres, Bull. geophysique de l'Institut des Recherches Geophysiques Nr. 10, Moscou, 1926.
(3) H. Koschmieder, Methods and results of definite rain measurements.
   III. Hydrolog. Conference of the Baltic States, Warsaw, 1930.
   IV. Hydrolog. Conference of the Baltic States, Leningrad, 1933.
(4) A sunken rain gage has been in use for nearly 20 years at the Sloutzk Meteorological Observatory at Leningrad (Director Sawinoff). However, this gage is not protected against spray.
(5) Almost 100 years ago the Englishman Th. Stevenson suggested a similar rain gage (Dinglers Polytechnical Journal, 86, p. 28, 1842). This suggestion had been completely forgotten. Neither in the experiment of Jevons, 1861, nor in the textbook literature is it mentioned. I myself received knowledge of Stevenson's suggestion only through the Patent Office. Stevenson suffered the same fate with his suggestion as Welsh with the aspiration thermometer; chiefly, perhaps, because he did not carry out experiments with his rain gage.
(6) The honeycomb rain gage is very similar to the pit gage of A. Buchan, which makes use of a network as compensation for the earth's surface. This compensation is certainly not as adequately sufficient as the honeycomb grate I used; also the net has a technical disadvantage in that the exchange of the rain gage is not very simple. On the other hand, the honeycomb grate can be stepped on so that placing and removing the gage offers no difficulty. Compare in this respect also the experiments of C. D. Stewart (Quar. J., R. Met. Soc., 62, 1926) which refers to a suggestion of E. Gold (Met. Mag., 57, 1922). Both works were not accessible to me in the original.
(7) Wind velocities and directions from the registers on the 17-meter high tower of the Schneekoppe Observatory.
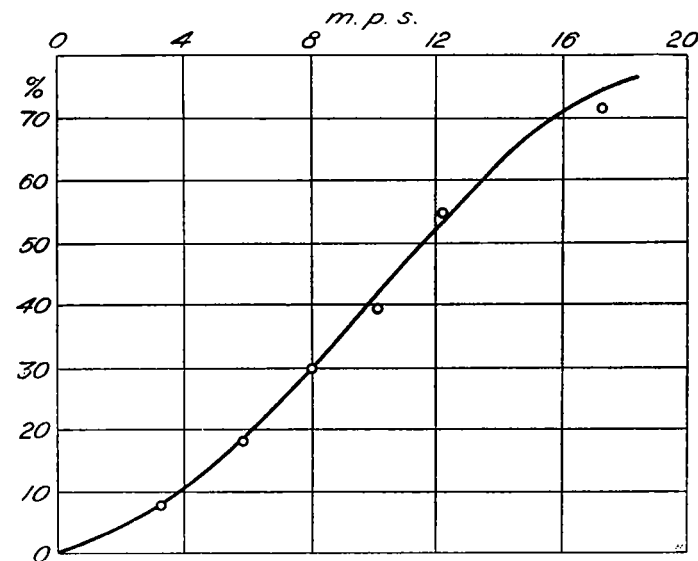(8) Uncorrected 74.2 mm.
(9) Uncorrected 145.1 mm.

FIGURE 4.—The amount of error of the normal upright rain gage (Jevons effect) in percent of the true amount of rain as a function of the wind velocity at the elevation of the catchment surface (110 cm).